# MEDICAL PROVISION FOR LONG SPACE FLIGHTS

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Space flight is always associated with the overcoming of gravitational forces, /439
and the weight and dimensions of the spacecraft at each stage of space exploration are restricted. For this reason medical provision for space flight is based on the principles of unification and universalization of medical equipment and the reduction in their weight by replacing metallic parts of instruments by synthetic products and by discarding ballast material from standard therapeutic forms. However, while adhering to these principles, it is impossible to include in the dispensary on board the spacecraft all the variety of medical equipment used on earth. Furthermore, this is unnecessary. The presence of medicines for the treatment of diseases not encountered during space flight (some chronic and endemic diseases, diseases associated with specific ages, diseases caused by insect and snake bites, etc.) would simply complicate the furnishing of such a dispensary. On board the spacecraft there must be only those medicines essential for treating the most probable or all the possible diseases and disorders arising during flight. These include the sequelae of physiological changes observed during space flights and in experiments simulating space flights (changes in endocrine influences, in the hemodynamics, the coagulation of the blood, decalcification of bones, dehydration of tissues, disorientation of the kinetic receptor apparatus, and so on).

A sudden increase in radiation associated with chromosphere activity of the sun may produce radiation sickness. Although as a result of the combined action of cosmic factors during a prolonged flight new and as yet unknown diseases may arise, the most likely event is the appearance of diseases encountered on earth, particularly in isolated groups of sailors and polar explorers [1]. Such persons are exposed for long periods to the action of extreme conditions, they remain for long periods under conditions close to those of space flight, and their morbidity may serve for guidance when forecasting morbidity among astronauts during long space flights, and hence, for forecasting equipment and materials necessary (P. V. Buyanov, V. G. Terent'yev, G. L. Yaroshenko). On these grounds, the probability of appearance of certain diseases has been calculated mathematically /440
and as a function of length of stay under extreme conditions (duration of space flight) and of the number of persons involved.* The calculation was made from morbidity data among polar explorers during wintering at stations within the Antartic continent. All the explorers had passed a preliminary medical examination, including tests of tolerance to moderate degrees of anoxia in a pressure chamber, and were accepted as suitable for activity connected with their occupation. They were mainly young (under 40 years of age).

An attempt was made to determine the probability of illness among members of the crew of a spacecraft during a flight of long duration. The character of this investigation is determined by the type of statistical model of distribution

*Crews consisting of men are envisaged.

which should be used for its solution. The Poisson distribution is a suitable model for this purpose, and is the one usually used to study rare events.

When using Poisson's law, the occurrence of the expected event is simulated by a point falling within a given segment $l$ along the axis ox. In this case the probability of occurrence of m points in segment $l$ is expressed by the formula

$$P_m = \frac{(\lambda l)^m}{m!} e^{-\lambda l},$$

where $\lambda$ represents the mathematical expectancy of the number of points per unit of length (or the statistical probability of the event).

The probability that no point shall fall within the given segment $l$ is given by:

$$P_0 = \frac{(\lambda \cdot l)^0}{0!} e^{-\lambda l} = e^{-\lambda l}.$$

Finally, the probability $R_1$ that any one point shall fall within the given segment is given by:

$$R_1 = 1 - P_0 = 1 - e^{-\lambda l}.$$

Let us now turn to the conditions of our investigation. We can state that the probability of any one attack of a certain disease among members of the crew during a given time interval can be expressed by the analogous formula:

$$R_1 = 1 - e^{-(n \cdot \lambda_i \cdot \tau)},$$

where n represents the number of members of the crew; $\lambda_i$ the statistical probability of an attack of the given disease; and $\tau$ the assigned time interval.

The last formula is the basis for our calculations. By substituting different values of n, $\lambda_i$ and $\tau$, values of the probability that members of the crew will suffer from a particular disease can be calculated for flights of different durations.

The results of calculations using Eq. (4) for certain diseases are given in Table 1.

As Table 1 shows, the probability of occurrence of diseases rises with an increase in the number of persons and in the duration of their stay under extreme conditions. The probability of certain diseases for a crew of 10-15 persons, /442
moreover, tends toward unity with an increase in length of exposure, i.e., these diseases are found during space flight under certain conditions and astronauts must be prepared to give medical assistance should they appear. The least

TABLE 1. Probability of Occurrence of Certain Diseases as a Function of Number of Crew Members and Periods of Duration under Extreme Conditions

| Illness | Duration of flight, months | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | | | 3 | | | | 6 | | | | 12 | | | |
| | 1* | 3 | 10 | 15 | 1 | 3 | 10 | 15 | 1 | 3 | 10 | 15 | 1 | 3 | 10 | 15 |
| 1. Angina | 0,00 | 0,02 | 0,05 | 0,08 | 0,01 | 0,03 | 0,10 | 0,15 | 0,03 | 0,09 | 0,27 | 0,38 | 0,06 | 0,18 | 0,48 | 0,62 |
| 2. Pulmonary tuberculosis | 0,00 | 0,00 | 0,02 | 0,03 | 0,00 | 0,01 | 0,03 | 0,05 | 0,01 | 0,03 | 0,09 | 0,14 | 0,02 | 0,06 | 0,18 | 0,25 |
| 3. Wounds, contusions, strains | 0,01 | 0,02 | 0,09 | 0,14 | 0,02 | 0,06 | 0,17 | 0,25 | 0,06 | 0,16 | 0,44 | 0,58 | 0,11 | 0,30 | 0,68 | 0,82 |
| 4. Diseases of the central and peripheral nervous system and mental disorders | 0,01 | 0,03 | 0,10 | 0,16 | 0,02 | 0,07 | 0,20 | 0,28 | 0,07 | 0,18 | 0,49 | 0,64 | 0,12 | 0,33 | 0,74 | 0,87 |
| 5. Diseases of the lungs of nontuberculous origin | 0,01 | 0,02 | 0,09 | 0,12 | 0,02 | 0,05 | 0,16 | 0,24 | 0,05 | 0,15 | 0,42 | 0,56 | 0,10 | 0,28 | 0,66 | 0,81 |
| 6. Diseases of heart muscle and vessels | 0,02 | 0,06 | 0,19 | 0,27 | 0,04 | 0,12 | 0,34 | 0,47 | 0,12 | 0,32 | 0,72 | 0,85 | 0,22 | 0,53 | 0,92 | 0,98 |
| 7. Diseases of digestive organs | 0,00 | 0,00 | 0,02 | 0,03 | 0,00 | 0,01 | 0,04 | 0,06 | 0,01 | 0,04 | 0,12 | 0,18 | 0,02 | 0,08 | 0,23 | 0,32 |
| 8. Acute appendicitis | 0,00 | 0,01 | 0,04 | 0,06 | 0,00 | 0,02 | 0,08 | 0,12 | 0,02 | 0,08 | 0,23 | 0,32 | 0,05 | 0,14 | 0,40 | 0,54 |
| 9. Diseases of bones, muscles, joints | 0,02 | 0,08 | 0,23 | 0,33 | 0,05 | 0,15 | 0,41 | 0,54 | 0,15 | 0,38 | 0,79 | 0,91 | 0,27 | 0,61 | 0,96 | 0,999 |
| 10. Suppurative diseases of the skin and subcutaneous cellular tissue | 0,02 | 0,06 | 0,18 | 0,26 | 0,04 | 0,12 | 0,33 | 0,45 | 0,11 | 0,30 | 0,70 | 0,84 | 0,22 | 0,51 | 0,91 | 0,97 |
| 11. Stones in the kidneys and Urinary tract | 0,00 | 0,00 | 0,01 | 0,02 | 0,00 | 0,00 | 0,02 | 0,03 | 0,00 | 0,02 | 0,06 | 0,10 | 0,01 | 0,04 | 0,12 | 0,18 |
| 12. Intestinal dyskinesias | 0,00 | 0,02 | 0,08 | 0,12 | 0,02 | 0,05 | 0,16 | 0,22 | 0,05 | 0,14 | 0,40 | 0,54 | 0,10 | 0,27 | 0,64 | 0,78 |
| 13. Diseases of the teeth and gums | 0,04 | 0,12 | 0,34 | 0,46 | 0,08 | 0,22 | 0,56 | 0,71 | 0,21 | 0,52 | 0,91 | 0,98 | 0,38 | 0,77 | 0,993 | 0,999 |
| 14. Sleep disturbances | 0,03 | 0,10 | 0,30 | 0,41 | 0,07 | 0,19 | 0,50 | 0,65 | 0,19 | 0,46 | 0,88 | 0,96 | 0,34 | 0,72 | 0,985 | 0,99 |

*Number of persons.

Commas represents decimal points.

probability to be taken into account in the calculation depends (according to the "principle of practical certainty") on the risk presented by the particular disease. The more dangerous the disease, the lower the probability of its appearance which must be taken into account, and conversely, the less the risk to health and working capacity presented by a disease, the greater its probability which can be disregarded. For example, if a group of 3 persons stays under extreme conditions for three months (Table 1), the probability of appearance of diseases of the heart and blood vessels is very low (0.12). However, considering the severity of the course and difficulty of diagnosis of these diseases, this probability of their occurrence must nevertheless be taken into account, and medical assistance must be regarded as essential. In the future, during the conquest of space, demands made on the functional capacity and training of astronauts are bound to increase, conditions of flight will be changed, and this must evidently result in some lowering of standards concerning the state of physical health. This may result in an increase in the number of cases of illness during prolonged space flights, and the problem of medical provision for them will become more urgent still.

As a result of the use of this approach to the problem of medical provision for prolonged space flights, taking into account the complete and systematic data available on morbidity of small groups of polar explorers, sailors making long single-handed voyages, experimental subjects, astronauts, and so on, we can:

a) forecast the most probable disturbances and diseases and the time of their appearance;

b) provide the necessary measures for their treatment and control;

c) determine the level of training of astronauts necessary for rendering medical assistance during flights of different durations and for crews consisting of different numbers of persons; and

d) determine flight conditions under which a physician must travel on board the spacecraft.

The suggested method may prove useful for the specification of optimal medical provision for expedition for whatever purpose.

## REFERENCE

1. Parin, V.V., Zakrzhevskiy, Ye.B. and Bayevskiy, R.M. Klinicheskaya Meditsina, No. 2, p. 3, 1965.